GenFit2 for sPHENIX tracking solution

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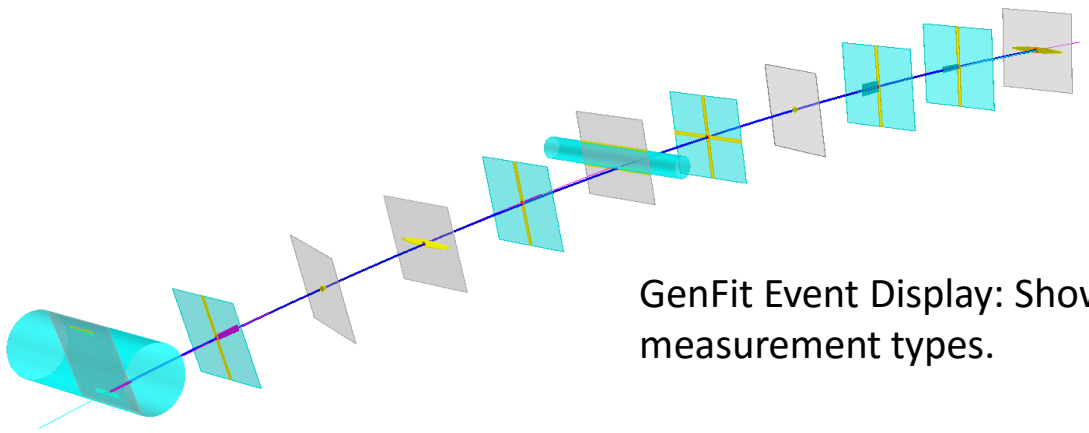
Motivation

- A good tracking solution for sPHENIX R&D and possibly future real data reconstruction.

- Advantages of GenFit2:
  - Generic open source tool
    - https://github.com/GenFit/GenFit
  - Tested in many experiments
    - Belle II, PANDA, SHiP, AFIS, GEM-TPC, FOPI, ...
  - Can handle realistic detector geometries



GenFit Event Display: Show different measurement types.

GenFit cont'd

- Developed for PandaRoot, and have been used in several experiments.
- Now is GenFit2 based on Belle II experience.
- GenFit de-couples the Fitting Algorithm with Specific Detector Setup. This is done by delegate the state/error propagation to the Track Representation (gen::AbsTrackRep)
  - TrackRep in GenFit context means handling error propagation, material effect, magnetic filed, etc. It means more than the choice coordinate system.

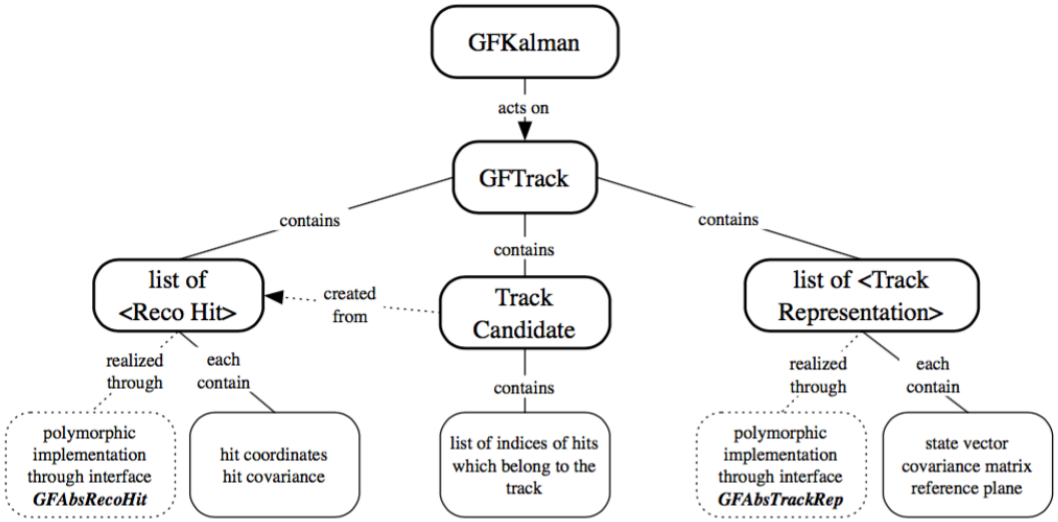


Figure 1.1: General structure of GENFIT.
http://genfit.sourceforge.net/GENFIT_v1_2.pdf

GenFit cont'd 2: RKTrackRep

- Use TGeo to describe the detector
  - sPHENIX detector could be ported to TGeo through GDML. (Abhisek has successful experience on that.)
  - Many experts (Abhisek , Chris, Jin, etc.) are working on it.
- Propagate through magnetic field: Runge-Kutta method
  - Geant4 used same model.
- Material effect (energy loss, multiple scattering, etc.): GenFit's own calculation.

Today's topic

- Explore and learn how GenFit works: logics, interfaces, etc.

- Test GenFit:
  - RKTrackRep Test:
    - Material effect
    - Charged particle through magnetic field
  - Fitter test:
    - Pull distributions
    - Momentum resolution

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How GenFit works

- Initiate GenFit with TGeo geometry and magnetic field.
- From Pattern Recognition:
  - (Sorted) detector hits (Measurement). Could handle small amount of outliers
  - Reference track (Seed)
- From measurements and reference track create a getfit::Track
- Choose a fitter (Kalman Filter, Deterministic Annealing Filter, etc.)
- Process Track
  - genfit::AbsFitter::process(getfit::Track)
- Extract fitting information from genfit::AbsFitterInfo

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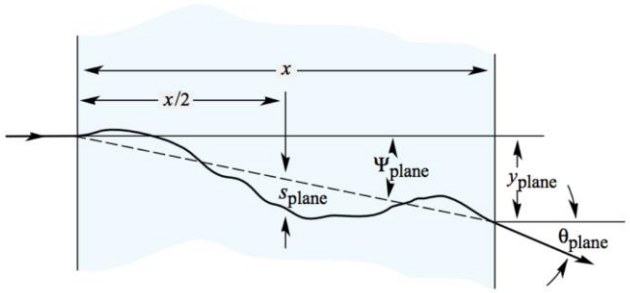
Test RKTrackRep: Multiple scattering

Procedure:
Propagate a mu+ with zero error cov matrix through 2cm thick material.
Then compare the the final state cov matrix with calculation.



$$\theta_0 = \frac{13.6\ \text{MeV}}{\beta c p}\, z\, \sqrt{x/X_0}\left[1 + 0.038 \ln(x/X_0)\right]$$

$$y^{\text{rms}}_{\text{plane}} = \frac{1}{\sqrt{3}}\, x\, \theta^{\text{rms}}_{\text{plane}} = \frac{1}{\sqrt{3}}\, x\, \theta_0 \ ,$$

2cm Pb, 10 GeV mu+	Calculation	RKTrackRep
θ0	0.0027	0.0029
y0 / cm	0.0031	0.0033

2cm Si, 10 GeV mu+	Calculation	RKTrackRep
θ0	0.00059	0.00066
y0 / cm	0.00068	0.00076

Test RKTrackRep: Lorentz Force

Propagate a mu+ in 2 Tesla magnetic field, in vacuum.
Compare the final state with calculation.
This is not completely trivial because this could be a good test that we used the right units.

Initial State (0 cm): 10 GeV mu+

```
3D position: TVector3 A 3D physics vector (x,y,z)=(0.000000,0.000000,0.000000)
3D momentum: TVector3 A 3D physics vector (x,y,z)=(0.000000,0.000000,10.000000)
```

Final State (10 cm)

```
3D position: TVector3 A 3D physics vector (x,y,z)=(0.000000,0.029980,10.000000)
3D momentum: TVector3 A 3D physics vector (x,y,z)=(0.000000,0.059958,9.999820)
```

Calculated py = 0.06 GeV

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- Test GenFit:
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    - Pull distributions
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Fitter Test

- 3 layers (5, 10, 15cm) of silicon cylinders, 50µm thick; In Air; 2 Tesla uniform magnetic field along z axis. A mu+ shoot in along x axis with some determined momentum

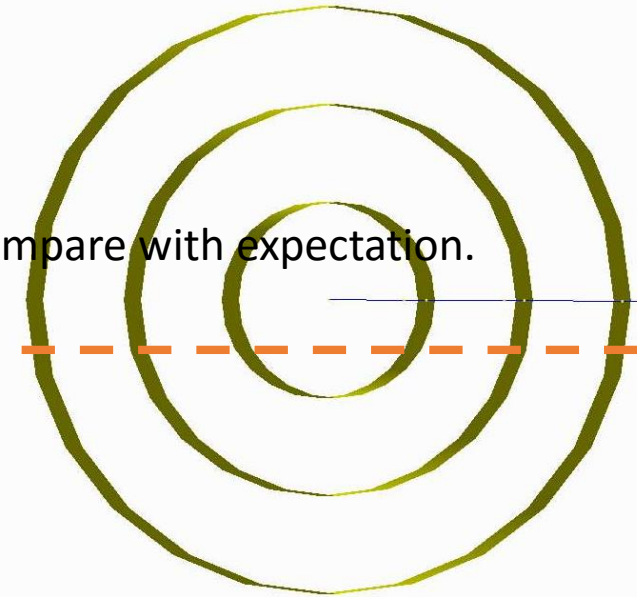
- Generate PHG4Hits based NTuple root file as input file for testing.

- Manually clone the detector set up in TGeo format

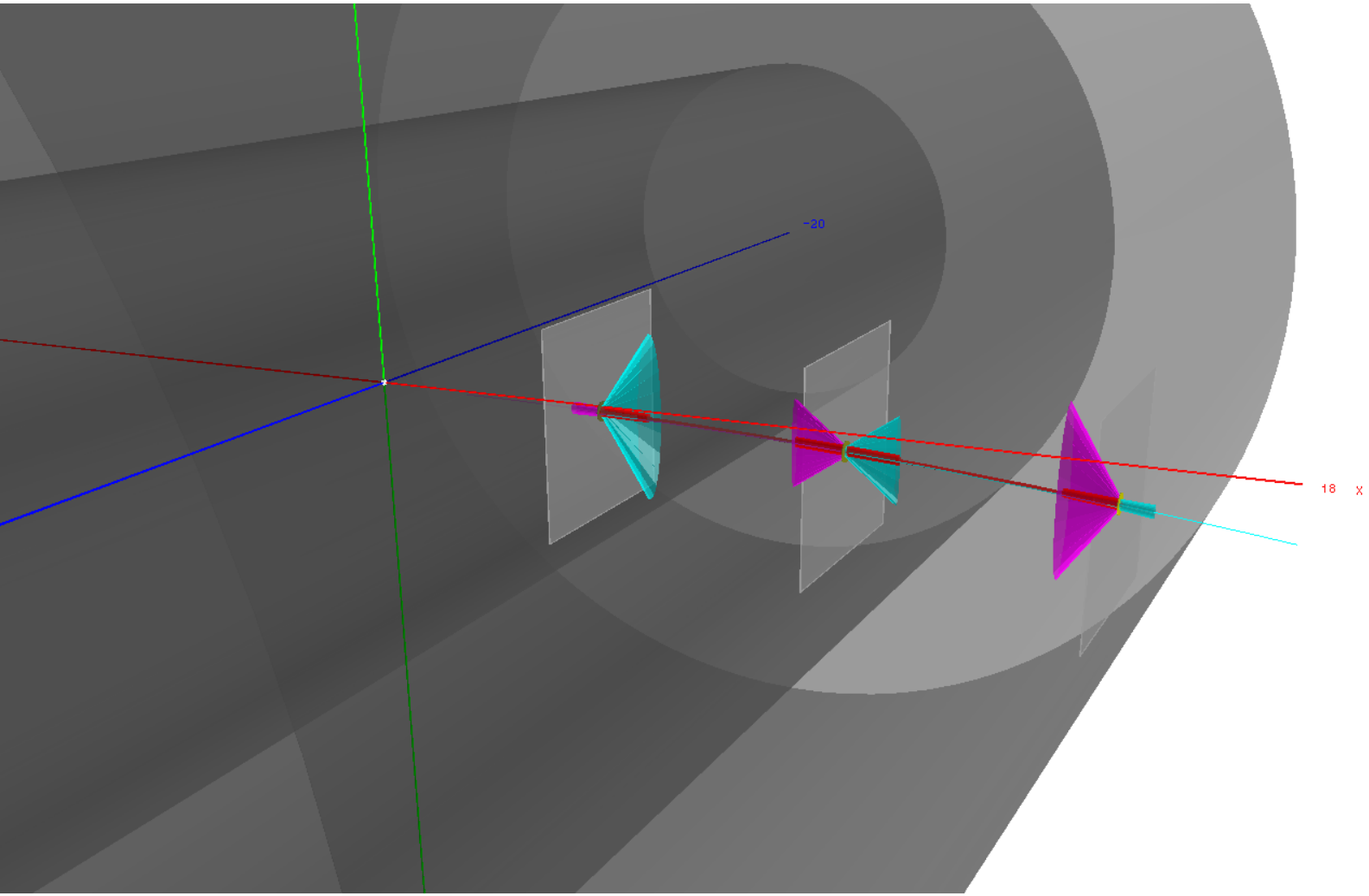
- Smear each PHG4Hits with a given resolution as the measurements.
- Smear the true information as GenFit seed.

- Do the fit.

- Draw the pull distribution, mom resolution. And compare with expectation.

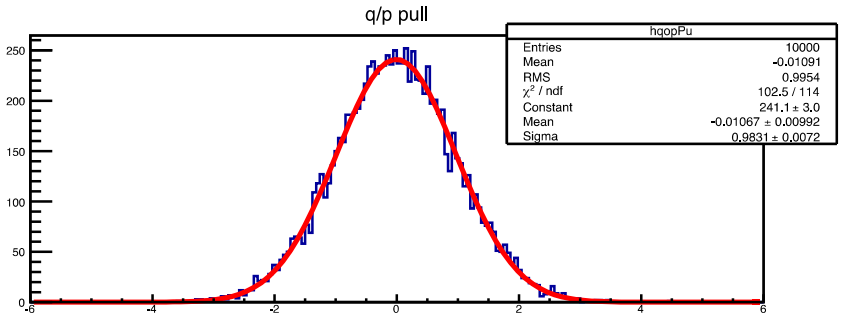


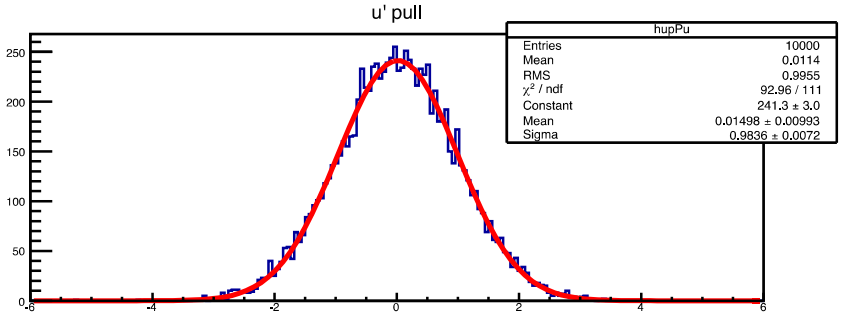
Event display

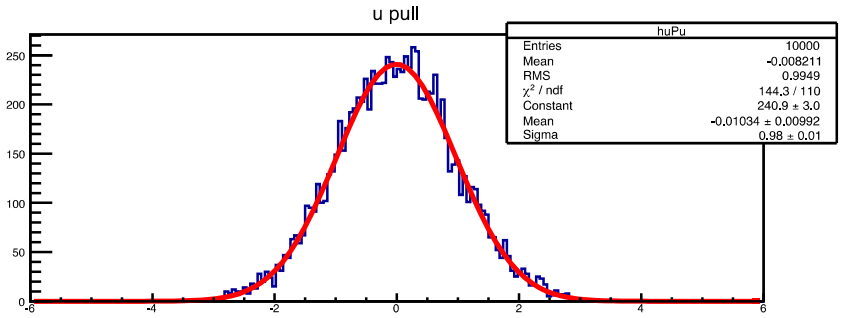


GenFit Event Display:
Smoothed track: weighted average between forward fit and backward fit.

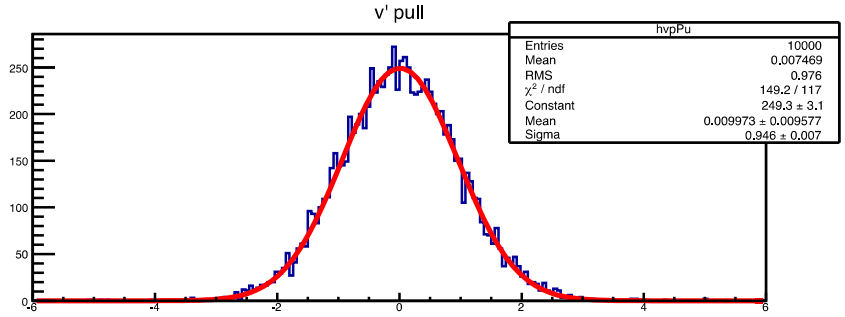
pull distribution

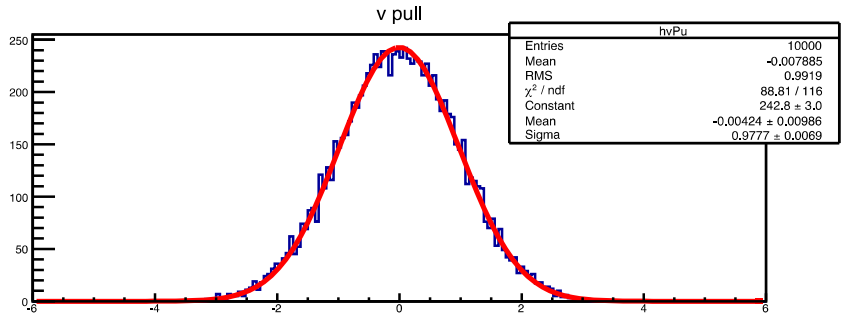






- State: (1/p, u',v',u, v).
- For all these pull distributions, the means are close to 0; the RMSs are close to 1.





Momentum resolution

δp/p = δSagitta/Sagitta

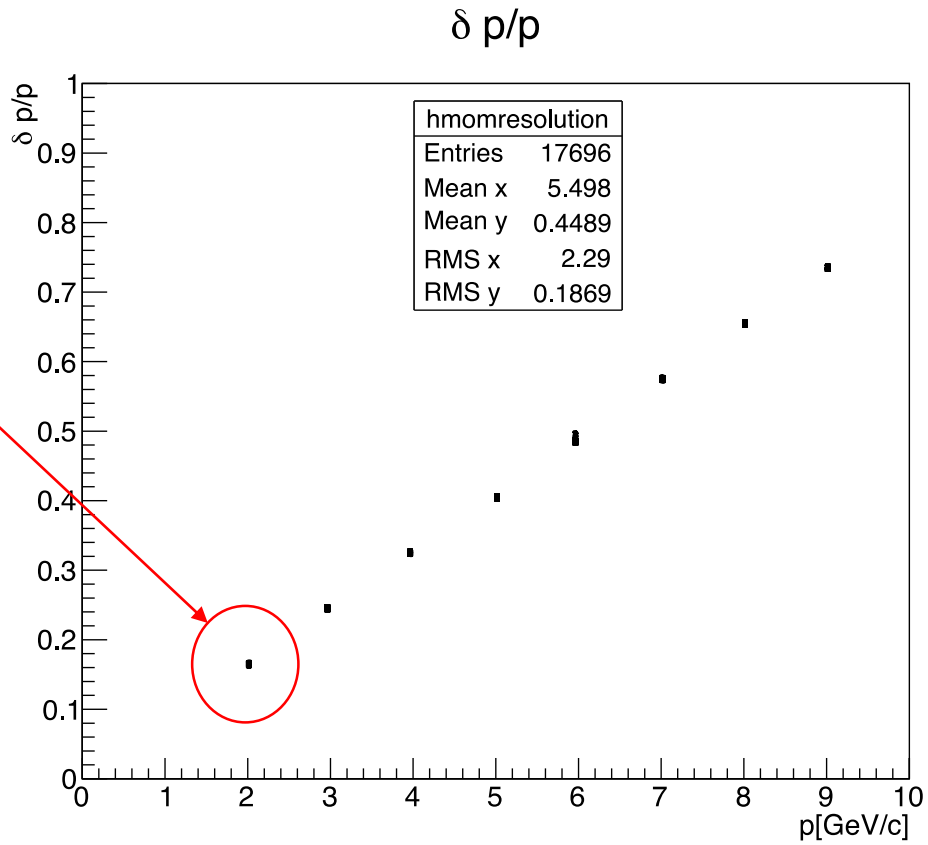
δSagitta = sqrt(1.5) × detector resolution (const here, 50 μm)

Sagitta ∝ 1/p (378 μm for 2GeV)

∴ δp/p ∝ p (16% for 2 GeV)

The fitted momentum resolution matches well with expectation.

In this testing case:
User CPU: 0.56ms/trk



Summary

GenFit is an generic tracking tool which has been tested in many experiments. It has many advantages. One caveat right now is that the default RKTrackRep is based on TGeo.

Current progress:

- Many experts (Abhisek , Chris, Jin, etc.) are working on porting the sPHENIX geometry to TGeo.
- Tested the default RKTrackRep in a standalone way. Fitter test in a semi-standalone way.

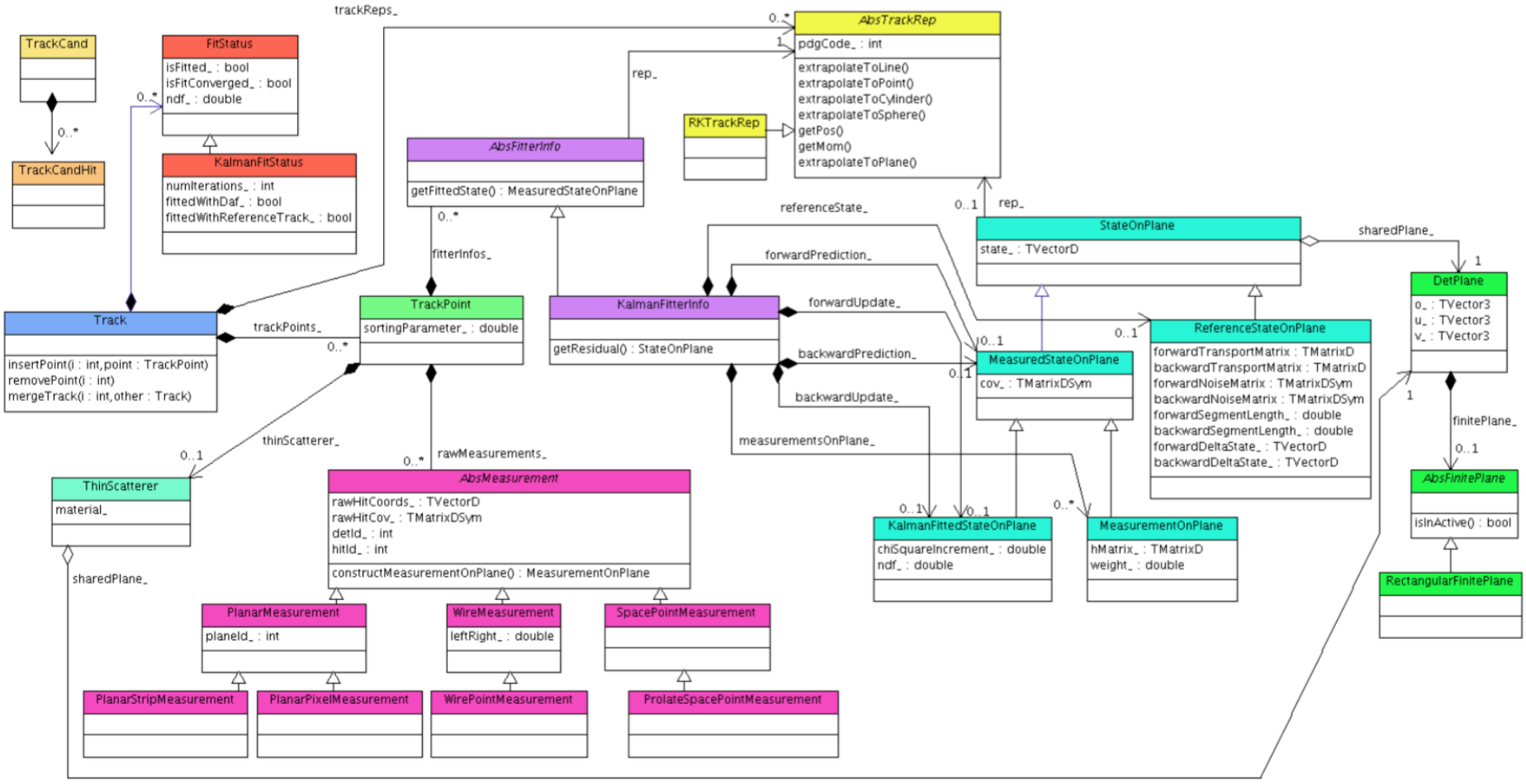
Next step:

- In this workshop: test fit sPHENIX simulated full silicon track. (Work with Jin.)
- Integrate GenFit2 into sPHENIX realistic tracking. (Work with Mike, etc.)
- GenFit2 now comes with RAVE (vertexing tool). Could be useful.

- If TGeo had some unavoidable caveats, may need to make a Geant4 (Geant4e) based TrackRep. (Work with Kun, etc.)

Backups

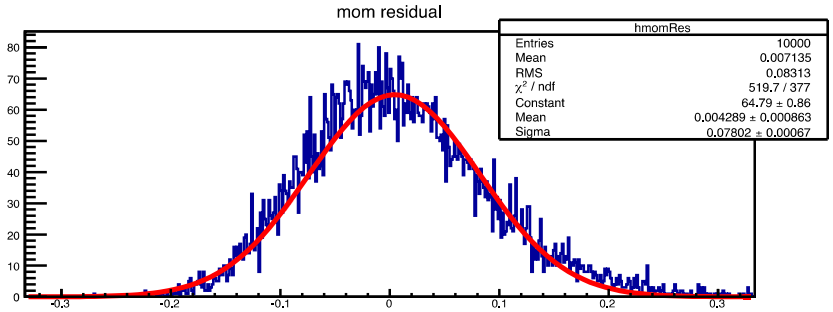
The data structure of GenFit2, genfit::Track

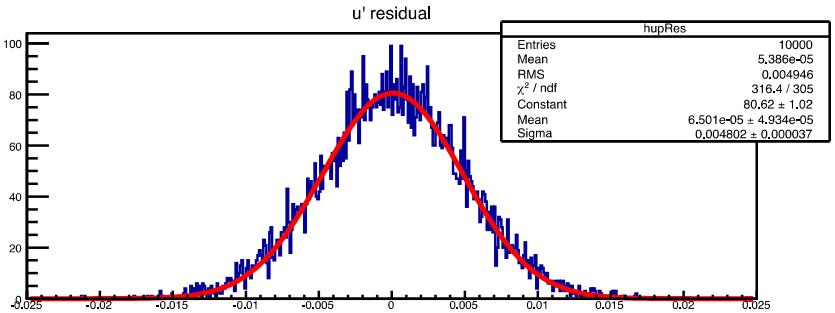


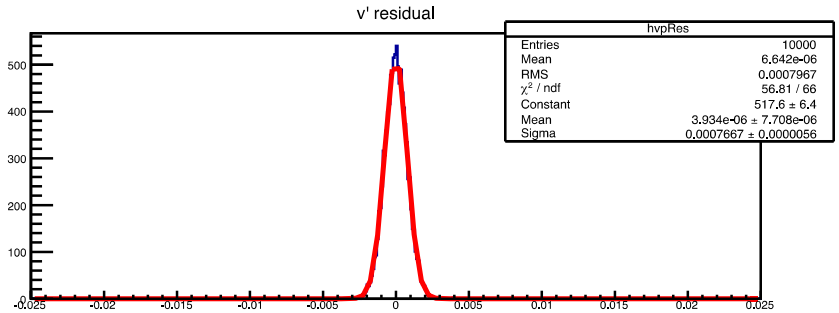
http://arxiv.org/pdf/1410.3698.pdf

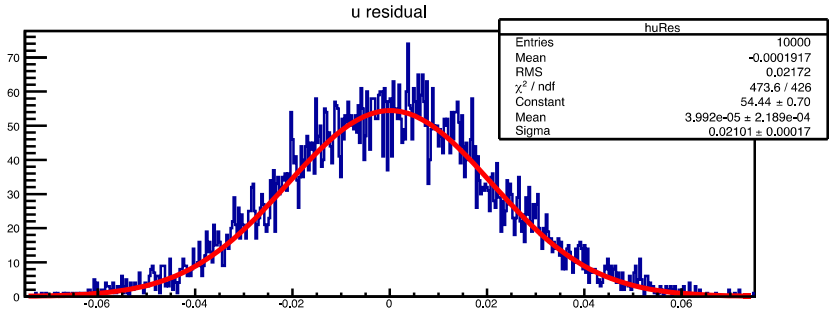
Residual definition 1

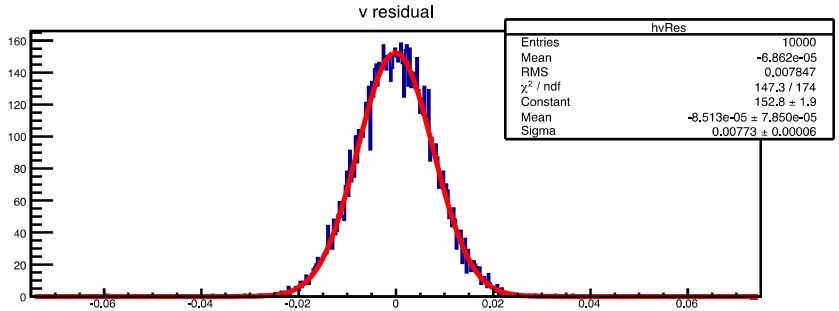
1GeV





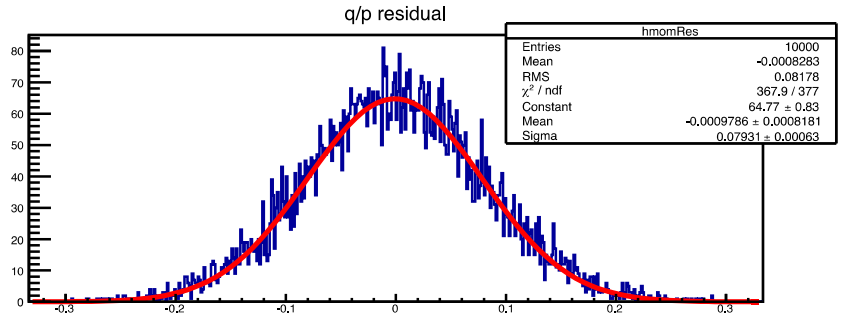


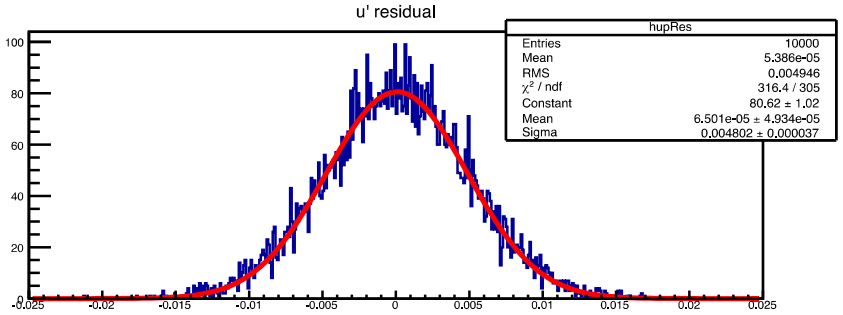


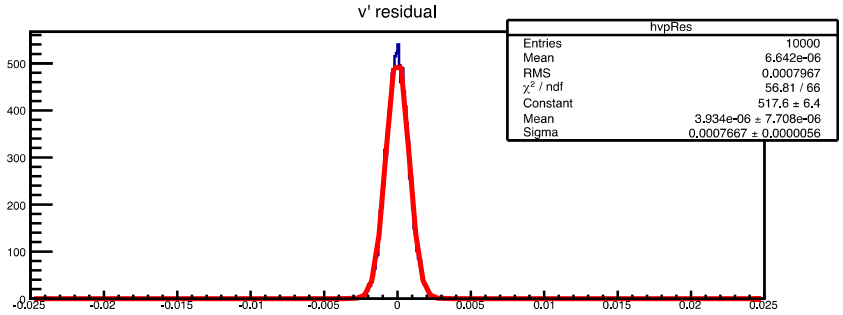


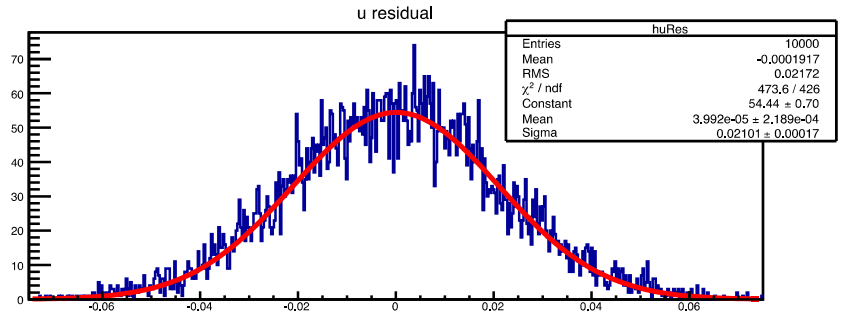
Residual definition 2

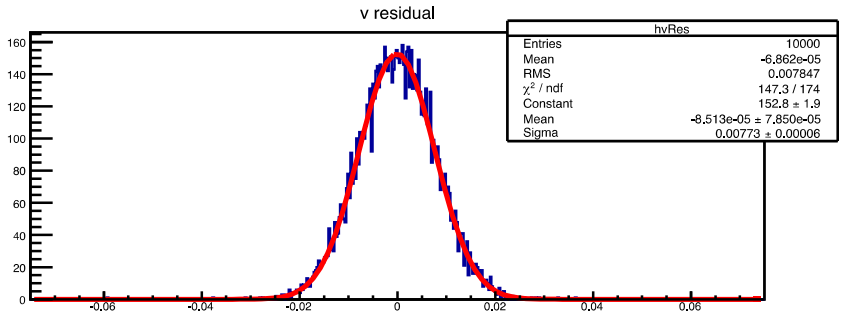
1GeV

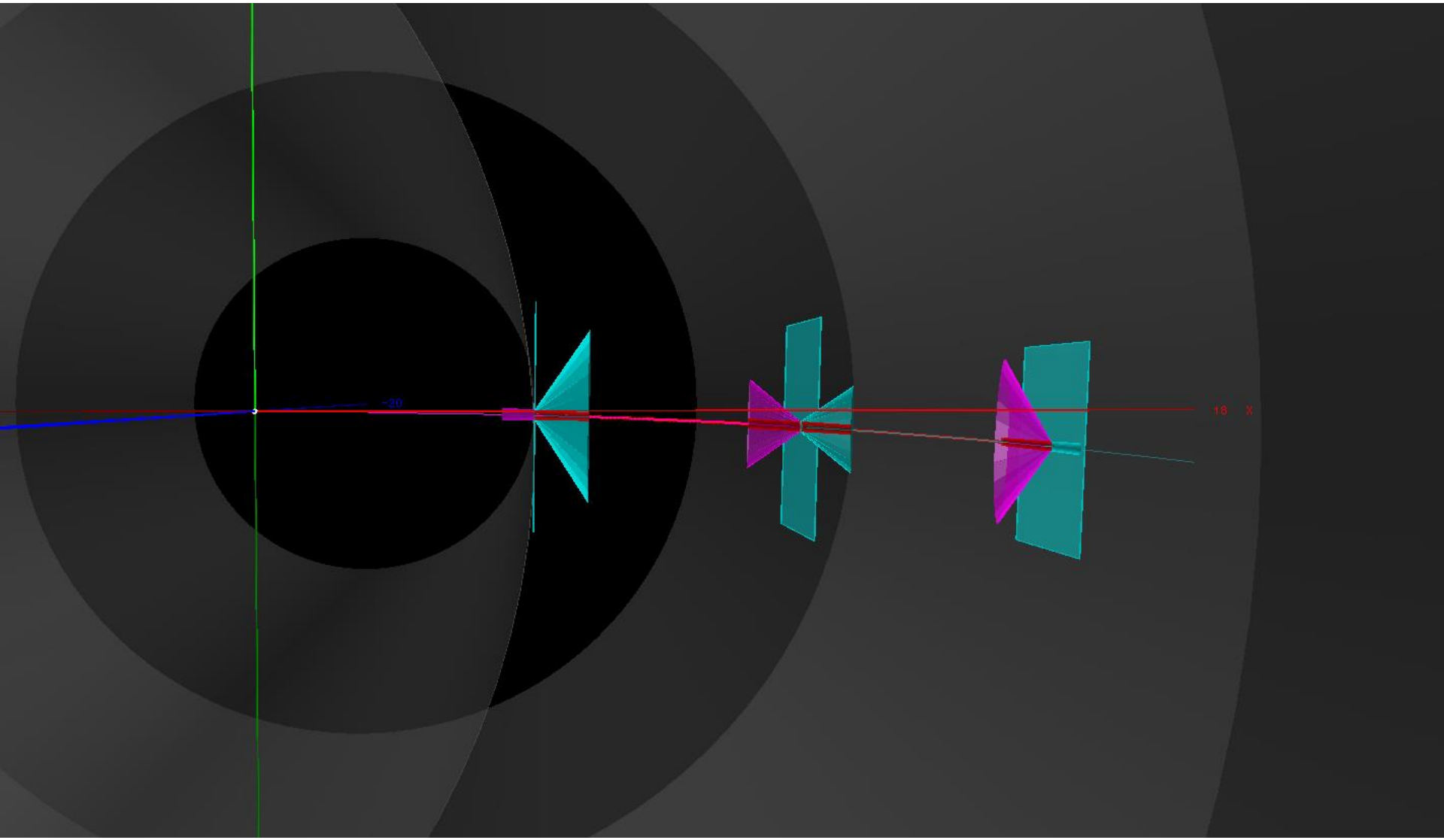








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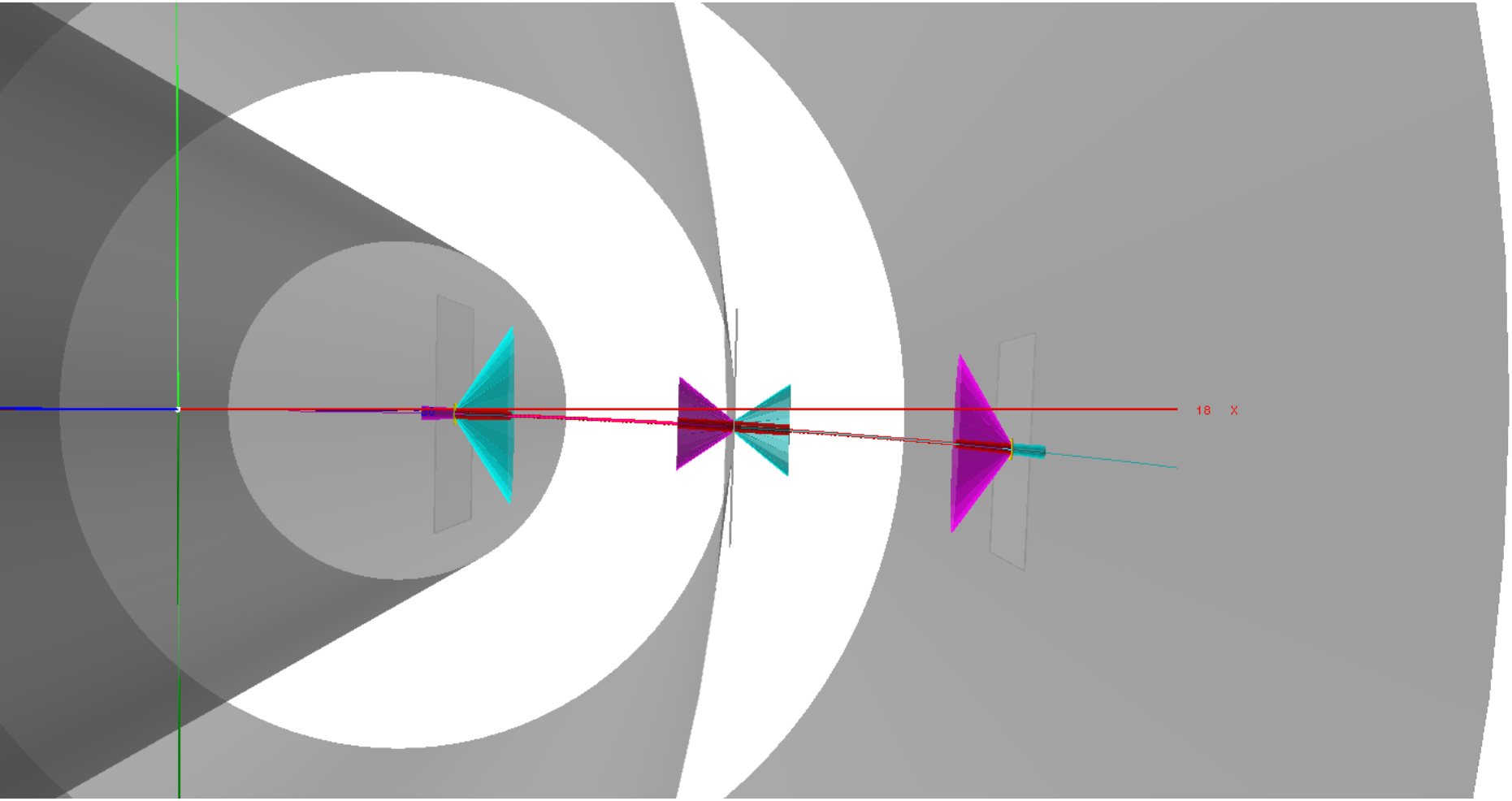
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